Consolidation in the Meat Sector

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Slaughter industries are consolidating, as the number of firms falls and plant sizes grow. Related changes are occurring in upstream livestock production sectors: large cattle feedlots and hog farms account for sharply growing shares of livestock sales. As in poultry, new contractual relationships have begun to replace spot market cash transactions for cattle and for hogs. Those sharp structural changes have raised concerns about market power, pollution control, and the reliability of traditional price reporting sources. This is a research conference, aimed at encouraging evaluation and discussion of research methods, data sources, and results.

Topics covered at the conference include the following:

* The existence, extent, and effects of market power in livestock and meat industries; Causal factors in consolidation, such as scale and scope economies, mergers, changes in product mix, innovation, and changes in contractual relations;

* Vertical coordination, as compared to spot markets for transferring livestock, including summaries of recent developments and implications for location, for product characteristics, and for price discovery;

* Externalities associated with consolidation, including the effects of larger animal production facilities on pollution and the effects of local control regulations on consolidation.

REGIONAL SHIFTS IN PORK PRODUCTION:

IMPLICATIONS FOR REGIONAL COMPETITION AND FOOD SAFETY

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The pork industry is undergoing two major structural changes. First, production and processing are consolidating into larger units; and second, production and processing are shifting out of the Midwest and into the Southeast. Production is no longer widely dispersed on feed grain producing farms. As production consolidates into large confinement operations, issues of local water and air pollution, animal welfare, and food safety hazards have received increased attention. At the same time, concentration of the processing sector has altered price discovery at the farm level. The shifting location of farm production interacts with both trends. It alters the regional markets between producers and processors and poses policy choices for states seeking to shape growth in local industry. In this regard, the pork industry reflects similar trends in other livestock industries.

In this paper, we explore a subset of these issues for the pork industry. A regional model of farm production supply and processing demand is constructed from USDA data and other sources. The model minimizes total costs of production and processing, taking into account differential costs by region and farm size, transportation costs from farm to processor, and

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differential costs by size of plant and use of overtime. This model is used first to simulate changes in industry costs and competitiveness during the 1990's. We explore how the changing location and concentration of farm production and processing has influenced the overall economic efficiency of the industry, the competitiveness of traditional producing areas, and the incentives to invest in new plants. Then we use the model to simulate the potential costs of reducing salmonella contamination in pork. Recent regulation of the processing sector requires reduced incidence of salmonella on pork carcasses. As processors meet this new standard, they may seek improved pathogen control from farm suppliers. Our results show how farm level control might interact with other changes to influence industry costs and future investments across regions.

The paper first discusses changes in the regional and size structure of pork production and processing. Next is a brief review of the model and data (details are in the appendices). The discussion of results proceeds by looking individually at specific changes and then at the overall system impacts of regional and structural change. Finally, we consider the implications of these changes for food safety improvement in pork.

Overview of Changes in the Pork Industry

A brief review of changes in the pork industry helps to set the stage for the model results. We first examine the changing structure and location of farm production. Hog production has historically been concentrated in the Midwest. Figure 1 shows the distribution of hog production from the county level 1992 Agricultural Census. Iowa alone accounts for 26 percent of U.S. production in 1992, and the other Midwestern producing states account for another 44 percent (Table 1). Production has been growing outside the traditional region, particularly in North

Carolina, which produced only 8 percent of U.S. hogs in 1992, but 17 percent in 1995. Total production in six southeastern states, AL, AR, GA, NC, SC, and VA, nearly doubled. Annual hog sales in those states increased from 9.2 million hogs (11.9%) in 1992 to 17.8 million hogs (21.6%) in 1995. In the traditional region, the losses of NE and IA farms' shares are substantial, 3.4 and 4.4%, respectively.

In addition to regional shifts, farm production structure is shifting rapidly towards fewer farms that produce larger numbers of hogs. The proportion of hogs produced on farms selling more than 7500 head annually has increased in both the traditional and emergent areas (Table 2), but most dramatically in the latter. For instance, the mega farms' total production in seven midwestern states IA, IL, IN, MN, MO, NE, and SD, increased from 5.5 million in 1992 to 8.2 million hogs in 1995, even though total production in those states declined from 59.1 million to 55.3 million hogs. On the other hand, the production increase by mega farms in six southeastern states, AL, AR, GA, NC, SC, and VA, has been 5.9 million hogs (6.8 million in 1992 versus 12.7 million in 1995) most of which occurred in NC (5.2 versus 10.6 million). These size categories reported in the Census do not give the full picture, because many of the new confinement operations have much larger annual sales than 7500 head (NPPC, 1995). Thus the change in unit size is even more dramatic than indicated by these data.

These changes are driven by economies of scale in hog production. The historical dominance of the Midwest region was based on the availability of relatively cheap feed stuffs produced on farm (McBride). This advantage still exists, but is no longer the driving force behind farm costs. We estimate that average costs of production per hog vary from $35.70/cwt on mega farms to $59.57/cwt on small farms. Regional feed costs differ between the emergent and traditional regions. For instance, in 1992, corn and meal prices were 2.01 \$/bu and 11.93 \$/ton, respectively, in the traditional region (averages of IA, IL and MN), while the corresponding prices in the emergent region were 2.29 \$/bu and 13.93 \$/ton (averages of AR, GA, and NC), respectively. This causes a feed cost advantage for midwestern mega farms, but the cost difference is only 2.10 \$/cwt. Thus, growth in the emergent region occurs mainly in the mega farms category that has a cost advantage over most producers in the traditional region, who still operate on a relatively smaller scale.

The processing sector has also undergone changes in scale and location. The vast majority of hogs (86% in 1995) are slaughtered and processed in plants that slaughter over 1,000,000 head annually. Although many thousands of smaller plants continue to operate, their share of slaughter has been declining over time (USDA Packers and Stockyards). Figure 1 shows the location of the 38 large plants that are included in our model. Table 3 shows their capacities in 1992, 1995, and 1998. These plants are primarily in the traditional hog producing region, but new capacity has been added in the emergent region and in the Great Plains. Many large plants have converted to double shift and can slaughter over 10,000 head per day. Hayenga estimates that the costs of processing vary from \$20 to \$22 per head, depending upon whether a plant can operate double shifts. Thus, there are economies of scale in processing as well as in farm production.

Changes in structure and location are also related to food safety hazards in pork. The USDA has imposed pathogen reduction regulation on the processing sector, and will require those pork plants with above average incidence of salmonella to reduce their incidence. USDA estimated that 8.7% of pork carcasses have detectable levels of salmonella (USDA Microbiological Baseline Survey). The on-farm incidence of salmonella is much higher, as reported by the USDA National Animal Health Monitoring Survey (NAHMS). The NAHMS data show clear patterns in the incidence of salmonella at the farm and pig level that vary by farm size and region (see Appendix C for details). The Southeast region has a higher incidence of salmonella than the Midwest; large farms have a higher incidence than small farms. So, the percentage of pigs with salmonella varies from 44% on large southeastern farms to 9% on small midwestern farms. For instance, average contamination rates are estimated as 9 and 13% for small farms (producing less than 1000 hogs per year) in the Midwest and Eastern Corn Belt, respectively, while the corresponding ratios for very large farms (producing more than 7500 hogs per year) in those regions are estimated as 24 and 37%, respectively. An equally important observation is that hog farms in the Southeast (including NC, Georgia and Kentucky) have a substantially higher average contamination rate than the farms of same size in other regions. For instance, very large farms in the Southeast, which dominate hog production in the emergent area in recent years, have nearly two times the contamination rate that is estimated for their counterparts in the Midwest (44% versus 24%). Thus, if processors look to delivery of fewer hogs with salmonella as a way to reduce the incidence at the processing level, then large farms and southeastern farms would be most effected.

This study aims at an economic evaluation of the structural changes described above and determining the trade off between economic and food safety objectives. It investigates the impact of risk reduction regulations upon production, transportation and processing in the U.S. pork industry in a quantitative modeling framework.

An Overview of the Model and Data Sources

The model is a linear program (LP) that minimizes total cost to the pork industry, taking into account the costs of farm production, transportation, and processing. This is done in two stages, first at an aggregate (state) level, and then at county level. In the first stage, geographic locations of aggregate representative farms (regions or states) are determined by weighted averages of the locations of counties in each region, where the weights are supply shares of individual counties, and the entire regional supply is assumed to be concentrated at one location. This approach may underestimate the transportation costs corresponding to a particular delivery plan, but it leads to a model with manageable size[2]. In order to reduce aggregation errors and obtain a disaggregate optimum delivery pattern at county level, a second LP is developed and solved for each region separately. This model finds the minimum-cost regional production, delivery and processing schedule where total flows from all counties in a region to a processing plant equals the amount shipped from that region to that plant in the aggregate LP model solution. Appendix A presents algebraic details of the two models.

Both models include representative costs for five farm size categories determined by number of hogs sold annually. Farm costs also vary with regional differences in feed prices. In the first-stage model, production is aggregated for four regions in Iowa, six regions in Illinois, and for each of the remaining 28 states producing hogs. Each of the 48 large plants that operated in any of 1992, 1995, or 1998 are included separately in the model. The percentage of supply

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[2] Even though a flow variable was not defined for pairs of regional representative farms and processing plants which are more than 1000 miles apart, the aggregate LP model contains 564 equations and 5440 variables.

processed by smaller plants by region is subtracted from farm supply before optimizing deliveries to the plants included in the analysis. Plant processing costs vary by size of plant and by whether overtime is utilized. Transportation costs vary with size and distance of delivery.

The model generates shadow prices for farm size categories by region and for each processing plant. These shadow prices represent the cost reduction for the entire pork industry resulting from increased farm production or plant processing at the margin (one additional hog produced or processed). Farms or plants with higher shadow prices provide greater cost savings to marginal expansion, and thus are more profitable than farms or plants with lower shadow prices. Thus, shadow prices provide a measure of competitiveness, and show which farm categories or plants will likely expand production in the future. For farms, shadow prices (marginal opportunity costs) are determined by: 1) production cost advantage due to economic efficiency and regional input prices, 2) proximity to processing plants and relative economic efficiency of those plants. For processing plants, the shadow price of the processing capacity constraint is determined by processing costs in the plant as well as its proximity to major supplying regions.

The data base of the model is compiled from several sources. Data regarding farm structure of sales are taken from the 1992 Agriculture Census, and updated to 1995 using USDA reports (see Appendix B). Farm cost data are from analyses by USDA and Purdue University. Feed prices are from USDA. Processing capacity and costs data are obtained from Prof. Marvin Hayenga at Iowa State University, the NPPC, and the USDA/GIPSA. Transportation costs are from USDA and the BLS. Salmonella incidence is from the USDA/APHIS (see Appendix C).

Discussion of Model Results

In order to understand the influence of changes in regional and size structure separately at the farm and processing level, we first generated a model based on 1992 data. Then, farm structure, processing structure, or costs are changed to the 1995 level to see their separate impacts on industry costs and regional competitiveness. Model results are identified by two symbols, S for supply and P for processing, followed by a number indicating the year of reference for hog supply and processing capacity (see Table 4).

The impact of changing processing structure between 1992 and 1995

We compare the S92/P95 and S92/P92 model results to examine the impacts of changes in processing structure (plant locations and capacities) from 1992 to 1995. All other elements, i.e., regional farm supply structure and costs, are assumed unchanged. In 1995, several plants were either retired or temporarily closed for renovation and expansion (Table 3). Major plant closings occurred in the peripheral of the traditional supply area[3]. From 1992 to 1995, total capacity loss in six Midwest states only, IA, IL, IN, MN, SD and MO, was about 45 thousand hogs per day, which corresponds to 20 percent of the total processing capacity in those states. In contrast, significant capacity expansion occurred in a few plants in the emergent region, particularly in NC[4].

The model results show that total cost to the industry increases marginally, by $1.8 million

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[3] Daily processing capacities in 1992 and 1995 for some selected plants are as follows: ALBER_MN:8-0, CINCI_OH: 5-0, DMOIN_IA: 5.5-0, DUBUQ_IA: 11-0, HURON_SD: 5.8-0, LOGAN_IN: 6.1-0, MARCH_MO: 8-0, and STJOS_MO: 9.6-0 (in 1000 hogs)

[4] Total capacity expansion in two NC plants only, namely TARHI_NC (2-24) and CLINT_NC (0-6), was 28.0 thousand hogs per day.

a year, as a result of the changes in processing capacity. The savings in production and delivery costs ($1.2 million) are offset by the increase in processing cost ($3 million). This is because a significant part of the supply by Midwest farms would have to be processed either by more remote plants or by using more overtime capacity. The first of the above results is evident in Table 4, which shows that percentages of transportation flows in the 0-50 mile and 200+ mile ranges would decline, but more hogs would be shipped between 50 to 200 miles in 1995. The results presented in Table 5 show that overtime capacity utilization would increase substantially in the traditional area. The increase in overtime processing implies a higher cost for processing additional supplies in the regions surrounding those plants. Consequently, marginal farm production in this area falls in value, as indicated by the shadow prices of farm supply constraints in Table 6. The results show declining shadow prices associated with the supply constraints of farms in regions where processing capacity becomes more restrictive, as is the case for the traditional area.

According to Table 6, Midwest farms have higher shadow prices than the farms in the emergent area in 1992, with the difference ranging between $6 to $15 per hog. However, in the S92/P95 run, the Midwest farms would lose about $4-7 of their comparative advantage depending on the farm size and location. In contrast, as a result of increasing processing capacity in the emergent area in 1995, farms in that region (especially in NC) have higher shadow prices because their supplies would be shipped shorter distances to local plants[5]. The results show that the shadow price gain would be about $1.50 to $3 per hog. Although the traditional area farms still

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[5] All of the supply by NC farms would be processed by TARHI_NC and CLINT_NC plants, instead of SMITH_VA.

possess higher shadow prices than the emergent area, their relative situation would be weakened as a result of the assumed structural change in processing capacity from 1992 to 1995.

Processing plants experience the inverse change in regional competitiveness. Shadow prices of plants' processing capacity constraints, presented in Table 7, show that most of the Midwest plants would either preserve their shadow prices or become relatively more valuable than before, because of the higher demand for their processing capacity in the S92/P95 solution. On the other hand, plants in the emergent area have diminished shadow prices as new plants open there. The exception is the NC plants, which maintain their relative importance because of their proximity to major supply centers and the relatively limited processing capacity in this region.

Table 7 reveals interesting information about several plants which were closed in 1995 and then reopened with expanded capacities. For instance, LOGAN_IN and MARCH_MO were closed in 1995, but reopened in 1998 with increased capacities[6]. These plants possess the highest shadow prices in 1992, which demonstrates why they should be expanded. Another example is AUSTI_MN , one of the plants with the highest shadow price of $24.23, which increased its processing capacity continuously after 1992[7]. An exception is HURON_SD, which was closed in 1995 and then reopened in 1998 with a slightly increased capacity (5.8 vs 7.6). This plant has a relatively low shadow price in 1992, so the capacity expansion in 1998 is not justified under the assumptions of the model. Unless its technical efficiency is improved, this plant may have to be

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[6] The capacities of these two plants were 6.1 in 1992 vs 15 in 1998 (in thousand hogs per day), and 8 in 1992 vs 11.8 in 1998, respectively (see Table 3).

[7] This plant increased its processing capacity from 11 in 1992 to 13 in 1995, and then to 16 thousand hogs per day in 1998.

operating at the margin in the future. On the other hand, three plants that closed or downsized, namely ALBER_MN, CINCI_OH and STJOS_MO, had low 1992 shadow prices. Therefore, closing or downsizing those plants is justified, according to the model results.

In the emergent area, the shadow price for TARHI_NC is $24.23 both in 1992 and 1995, the highest shadow price also possessed by many profitable Midwest processors. This plant also expanded its capacity continuously (from 8 in 1992 to 24 in 1995, and then to 32 thousand hogs per day in 1998). This expansion is driven by the continuous increase in the amount of hogs supplied by NC. Accordingly, the shadow price of SMITH_VA declined from its high value of $24.23 in the S92/P92 solution to $20.50 in the S92/P95 solution, because a significant portion of the NC supply is now processed by TARHI_NC.

The Impact of Changes in Farm Supply Structure from 1992 to 1995

A comparison of the S95/P92 and S92/P92 model results quantifies the impacts of changes in farm supply structure only (hog sales by region and by farm size) from 1992 to 1995, assuming that all other things (i.e., spatial distribution of processing plants and their capacities, and costs of production/ processing) are unchanged. Changes in farm supply structure increase total cost for the industry by $592.5 million (Table 4). This does not mean as big an efficiency loss as it may first seem, since part of the cost increase is due to the expanded volume of the industry's output from 77.1 million hogs in 1992 to 82.4 million hogs in 1995. Average production and processing costs are estimated as $103.1 per hog in 1992 and $103.4 in 1995, indicating a slight marginal efficiency loss. Although more hogs are produced by larger and economically efficient farms, the resulting cost savings would be offset by increases in transportation and processing costs. This is because hogs are delivered longer distances and processed using more overtime capacity. Table 4 indicates dramatic changes in optimum transportation flows where long-distance deliveries increase substantially, by 9.1 and 11.5 % for 100-200 and 400+ mileage categories, respectively, while deliveries under 50 miles and between 50 to100 miles decline by 13.7 and 9.8%, respectively. Table 5 shows a large amount of overtime capacity utilization in many plants located in the traditional area. According to the S95/P92 solution, 835 thousand hogs would be processed by those plants using overtime capacity, which nearly triples the amount found in the S92/P92 solution (311 thousand).

Regional impacts vary substantially in the two runs. All farms in the traditional region show slight increases or decreases in their shadow prices, except the farms in IN, MO and OH (see Table 6). Farms in the latter states, however, see a decline in their shadow prices of about $6, 15, and 8 per hog. These losses in competitiveness of IN and OH farms are largely because of the supply increases in economically efficient farms in competing regions, particularly in NC, which supply hogs to the plants processing the supplies of farms in IN and OH. The shadow price change for MO farms is explained by the considerable supply increase in this state, which is not accompanied by a processing capacity increase (according to the model assumption). The situation is similar for farms in the emergent region, especially in NC where the shadow prices of farm supply constraints decline by more than $10 per hog.

According to the model results, shadow prices for processing plants near the regions with reduced supply would be adversely affected. Table 7 shows that shadow prices of several processing plants in the traditional area either remain the same or decline. On the other hand, plants in the emergent area maintain their shadow prices. This is because supply in that region increases substantially without a parallel increase in the regional processing capacity, and consequently those plants remain in high demand.

The Impact of Both Processing and Farm Structure Changes Together

The analyzes in the previous two sections aim at investigating the isolated impacts of changes in processing structure and farm supply structure, respectively, assuming that all other things remain the same. Here we compare the S95/P95 and S92/P92 solutions to investigate the comparative advantage implications of the same changes as they occurred simultaneously. When doing this, we assume that the supply and processing structures are as prevailed in 1995, but the production and processing costs are the same as in 1992. The reason for employing the 1992 costs is to isolate the effects of cost changes and also to facilitate a comparison of the model results in common units (1992 dollars). It should also be noted that the total volume of production and processing of hogs is assumed to be the same as the total volume observed in 1995. Thus, the S95/P95 run is simply a repetition of the S92/P92 run with the production and processing structures set at their 1995 values.

When the two solutions are compared, the first important observation is the dramatic change in optimum transportation flows (Table 4). While the percentages of 0-50 and 50-100 miles categories decline (by 6.8 and 5.4 percent, respectively), the percentage shares of shipments in 100-200 and 200-400 miles categories increase substantially (by 9.1 and 3.1 percent, respectively). As discussed earlier, the increase in minimum total cost over the S92/P92 run, \$497.6 million, cannot be interpreted directly as a loss of efficiency since the volume of hog sales (or processing) was increased in the S95/P95 run (by more than 5 million head). Total cost per hog (including production, transportation and processing costs) is perhaps a more meaningful indicator of the industry's overall economic efficiency. Average costs per hog in the S95/P95 and S92/P92 solutions are calculated as $102.54 and $103.08, respectively. This indicates an overall efficiency gain from the assumed structural changes, but the gain is small. Shadow prices of farm supply constraints, which are $4-8 less than the S92/P92 values for most farms both in the traditional and emergent areas, show significant efficiency gains on the supply side. The shadow price reductions indicate that incremental cost of the last unit produced by each farm category is lowered in 1995. This is due primarily to expansion in larger and economically more efficient farms' supplies in 1995. This can also be interpreted as a reduction in profitability of farms in a competitive environment because prices will be pulled down by economically efficient farms, which will threaten the viability of small and economically inefficient farms.

Shadow prices of the plants' processing capacity constraints show that most plants located in the traditional area have reduced shadow prices (Table 7). On the other hand, shadow prices of the plants in the emergent area show significant increases, indicating that those plants would improve their profitability because of the high demand for their processing capacity. The dramatic increase in the supply of large and very large farm categories in NC is the main reason for this.

Effects of Changes in Farm Costs

The performance of hog farms may have been affected by the input price increases observed during the 1992-1995 period. The prices of feed grains (particularly corn) and meals have gone up significantly after 1992 due to the changes in farm program provisions and reduced stocks following the 1993 flood year. The price increases have not been uniform across regions. For instance, corn prices in IA and IL were $2.00 and $2.11 per bushel in 1992, whereas the prices in 1995 were $3.20 and $3.30. In NC, on the other hand, the prices in 1992 and 1995 were $2.26 and $3.54, respectively. Recently, corn and meal prices declined back to the 1992 levels and even below. To capture the effects of farm input prices, the model was run with the regional crop and meal prices observed in 1995 assuming that the farm supply and plant processing structures are as observed in 1995. The results are compared against the previous run (S95/P95) that assumed the 1995 supply and processing structures and the 1992 input prices. It is seen that physical variables, namely optimum supply, processing and transportation flows, change only slightly (see the S95/P95/C95 row in Table 3). This indicates that regional variations in input costs of hog farms do not constitute a significant factor for the overall performance of the industry.

The Impact of Potential Supply and Processing

Previous sections discussed the effects of changes in supply structure alone, then changes in processing structure alone, and then the combined effects of simultaneous changes in both. The hog processing sector has undergone continued structural changes after 1995, where new plants were added to the system and some existing plants expanded their capacity significantly[8]. Some plants, on the other hand, were closed in 1995 and then reopened with the same or nearly the

[8] For instance, CHICA_IL, DOWNS-KS, GALVA_IL, WATER_WI, which were opened in 1995, have added a total processing capacity of 5.6 thousand hogs per day. On the other hand, AUSTI_MN, FREMO_NE, GUYMO_OK, LOGAN_IN, MARCH_MO, and TARHI_NC plants have increased their total processing capacity substantially, by about 45 thousand hogs per day.

same capacity in 1998 [9]. Whether or not individual plants that were in operation any point in time during 1992, 1995, or 1998 could survive as profitable operations under the structural changes in supply from 1992 to 1995 is the issue that we address here. It is assumed that: i) the total amount of hogs processed equals the actual amount observed in 1995, ii) the supply limit for each farm, by region and by farm size, is the maximum of its supply in 1992 and 1995, and iii) the capacity of each processing facility is the maximum of the capacities of that plant observed in 1992, 1995 and 1998. Both farm and processing costs were assumed to be the same as in 1992. Given that an excess capacity would exist under these assumptions, some plants may have to downsize their operation (by reducing capacity utilization) or may not operate at all. The purpose of the analysis here is to identify those processing facilities and farms that are economically viable and the ones at the margin or vulnerable if the full supply and processing potential of the industry were available in 1995.

The model results under these assumptions are presented in tables 4-6 in the SPMAX column. Since the total processed amount is set at the observed 1995 level, it is more meaningful to compare the results with those obtained in the S95/P95 run. A comparison of the total cost solutions shows that, under the assumptions stated above, the industry would save about $100 million (about 1.2%), $94 million of which is due to production and transportation cost savings (Table 4). A dramatic change would occur in the distribution of transportation flows among the distance categories. As shown in Table 4, more than 77% of the marketed hogs would be delivered to processing locations less than 100 miles distance from where they are produced

[9] DUBUQ_IA, HURON_SD, and WESTP_MS are three major plants in this category. Total capacity of these plants is about 24 thousand hogs per day.

(versus 51.3% in the S95/P95 run), while only 6% would be transported more than 200 miles (versus 18.8% in the S95/P95 run). This is because of either the processing capacity expansion near major supply centers (as in TARHI_NC), or the capacity that is assumed to exist (which was actually nonexistent) in 1995. Most of the plants in the traditional area would downsize their operations. Some plants would not operate at all, and many plants would reduce their regular-time capacity utilization substantially[10]. Total overtime capacity utilization in the Midwest region would fall from 1,596 thousand hogs to 151 thousand hogs. Naturally, overtime processing would be totally eliminated in those plants. In contrast, high capacity utilization in the emergent area plants would continue (particularly in NC plants).

On the supply side, small farms do not operate in almost all regions, due to their relatively high costs of production. Large and medium farms can more efficiently supply the 1995 level of processing demand. The exceptions are in Iowa, Minnesota, S. Dakota and West-Northwest Illinois counties, where proximity to processing facilities gives smaller farm operations an advantage over other regions. These results point to the inevitable shift away from smaller farm operations that is underway in the pork industry, but also highlight that small and medium operations will still be competitive in the core traditional production region.

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[10] Capacity utilization in the Midwest plants was typically around 98% in the S95/P95 run. Several plants, including ALBER_MN, CRETE_NE, DENIS_IA, DUBUQ_IA, OTTUM_IA, PERRY_IA, STORM_IA, WATER_IA, SIOUC_IA, DELPH_IN, LOGAN_IN, CRETE_NE, FREMO_NE, WORTH_MN, and HURON_SD, would reduce their capacity utilization to 80-90%. Some other plants would reduce their capacity utilization even further: AUSTI_MN (77%), BEARD_IL (71%), SIUXC_IA, MONMO_IL (66%), MARSH_IA, ROCHE_IL (64%), SIUXF_IA (46%), and STJOS_MO (29%). (CJUNC_IA, COLUM_OH, and CHICA_IL). CJUNC_IA, COLUM_OH, and CHICA_IL would be closed.

Impact of Limiting Salmonella Incidence in Hogs Delivered to Plants

Salmonella may enter the pork production chain from a variety of sources, starting with potential infection of animals on farm. As infected animals may continue to carry and shed the organism even when asymptomatic, cross-contamination may occur during transportation, lairage, slaughter, evisceration, or product fabrication (Bahnson et al.). If contaminated, organisms may grow on pork products that are mishandled at the wholesale, retail, or consumer level. The present analysis focuses on contamination at farm level only. Preliminary statistical results (Appendix C) from the USDA/NAHMS survey show that salmonella incidence is closely related to farm size, where large hog operations have a higher contamination ratio. The ratios vary regionally also, as mentioned earlier. Consequently, any efforts by processors to limit salmonella incidence in delivered hogs would directly affect the supply and processing structures, and the flow of hogs from farms to processing plants.

The analysis in this section aims at investigating the implications of imposing a restriction on expected contamination ratio prior to processing upon: i) the supply and processing structures, and ii) regional shadow prices for representative farms and processing plants. Imposing an upper bound on the average salmonella incidence at each processing plant is hypothesized here as one potential control measure. Such limits might be imposed implicitly if processors require quality assurance procedures from farm suppliers in order to reduce risk, or if processors identify salmonella-free farms for special processing days. These kinds of requirements would limit potential flows of hogs between certain farm categories and processors. We approximate the effects of such measures by limiting average prevalence in delivered hogs. The supply and processing structures are assumed to be the same as in the previous section (SPMAX). The model is solved by imposing various maximum contamination ratios, specified exogenously and varied parametrically over the range of 35-19%. In each run, a uniform maximum contamination ratio is assumed for all processing plants.

The results are presented in Table 8 for five benchmark ratios. It is seen that lowest risk level (ratio of contaminated animals to total processed amount in each plant) can be 19%, and beyond this level the model becomes infeasible. This is because there is not enough "safe" supply to accommodate the restriction on contamination ratio. Total cost to the industry would increase mainly due to the increases in farm production and delivery costs. The total cost increase in the case with the lowest salmonella risk is estimated as $252 million, or 3%, with respect to the no regulation case (i.e., SPMAX, see Table 4 and Table 8). The cost change occurs because of two reasons: i) as the maximum contamination ratio becomes more restrictive, processing plants, particularly those in the emergent region, would be required to obtain their hogs from more remote farms that have lower contamination ratios. This imposes higher transportation costs to those plants; ii) more hogs would be supplied by small and medium farms, which have lower contamination ratios than large and very large farms. This would increase production costs since small and medium farms have substantially higher production costs than the other farm groups. Distribution of hog deliveries would be affected dramatically. Under the 35% risk level, the share of deliveries under 100 miles is about 73%, whereas the corresponding proportion under the 19% risk level is only 55%. The farms in Midwest, particularly small farms, would be important suppliers both for local processors and remote processors in the emergent area. The share of Midwest farms in total production would increase from 64% (under 35% contamination rate) to

77% (under 19% contamination rate). As a result, all processing plants (including the ones that are actually closed in 1995 or 1998) in the traditional area would gain comparative advantage and increase their share in total processing, in most cases by increasing their overtime capacity utilization (Table 8).

Conclusions

Changes in the farm supply and processing structures have increased pork industry efficiency, but not as dramatically as might be expected. Larger farms and processors do have lower costs, but some of these cost reductions are offset by higher transportation costs as hogs move longer distances or by the overtime processing necessitated by the remaining imbalance between regional supply and demand. Our results point clearly, however, to the strong economic forces driving continued concentration of farm level production into larger units. Whether and how local pollution externalities or food safety concerns will work against this trend is unknown, but the results show that the forces behind the trend continue to influence regional and firm size comparative advantage, and thus marginal investments in the industry.

The regional changes in production, followed by complementary processing investments, are clearly driven by the ability of the emergent region to capture economies of scale in farm production. The Midwest has lost market share at the farm and processing level, and the shadow prices indicate that this will continue. However, small and medium farms in the traditional producing area do have the ability to compete with the emergent region, as long as processing capacity remains concentrated in the traditional region. When and if that processing capacity disappears, small and medium farms will be overtaken by more efficient mega farms.

Food safety is one of many emerging concerns for the pork industry, and one that is likely to interact with existing determinants of cost structure. We simulated the effects of imposing restrictions on the maximum salmonella contamination rate in hogs delivered to processing, based on the estimated contamination rates by farm size and region from the USDA/NAHMS survey. The structural changes and concentration in the pork industry that led to the dominance of large and mega farms and large processing facilities, especially in the emergent area, may have created an economically efficient industry but increased the potential for food safety hazards. The results of simulating restrictions on salmonella contamination show that total industry costs could increase by $250 million (3% over 1995 costs), mainly due to increases in farm production and delivery costs. Processing plants, particularly those in the emergent region, would have to deliver their hogs from more remote farms or from small and medium farms, that have lower contamination rates than the economically efficient large and mega farms in the emergent region. As a result, processing plants in the traditional area (including the ones that closed in 1995 or 1998) would gain comparative advantage and increase their share in total processing.

We must caution that these results are preliminary and provisional for at least two reasons-- we must rely on the only available national data source for estimated average contamination rates and we do not know if low cost farm level interventions to reduce salmonella risk may be feasible for mega farms in the future. Our model will allow us to analyze the impact of alternative farm level interventions in the future as on-going veterinary research discovers new methods of risk reduction.

Overall, the findings of the present study highlight the magnitude of structural change and economic losses involved if food safety in delivered hogs becomes an important industry issue. Unless low-cost measures can be taken at the farm or processing level to reduce salmonella contamination, food safety measures could present a serious threat for both the large farms and processors that became operational over the last decade. Therefore, it is in the interests of the pork industry to explore alternative farm management options, particularly on the newly introduced very large operations in the emergent area, to maintain and enhance consumers' safety as well as economic performance of the industry. Otherwise, it is possible that food safety concerns could reverse the dynamics of the pork industry observed in the past decade.

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Table 1: Supply Changes in Selected States in the Traditional and Emergent Areas (1000 hogs).

	1992	1995
Traditional Region		
Iowa	20,536 (26.6) [a/]	19,112 (23.2)
Illinois	7,447 (9.7)	6,901 (8.4)
Indiana	6,522 (8.5)	6,498 (7.9)
Minnesota	6,278 (8.1)	6,667 (8.1)
Missouri	4,283 (5.6)	6,222 (7.6)
Nebraska	6,387 (8.3)	3,234 (3.9)
S. Dakota	2,882 (3.7)	2,565 (3.1)
Subtotal	54,335	51,199
Emergent Region		
N. Carolina	5,934 (7.7)	13,779 (16.7)

Note: a/ figures in parentheses represent percentage shares in total market sales.

Table 2: Regional Hog Production by Farm Size in 1992 and 1995 (in 1000 heads)

	1992			1995		
	Traditional [a]	Emergent [b]	Total	Traditional	Emergent	Total
Small [c]	9,892	811	10,703	8,632	807	9,438
Medium	11,919	525	12,444	10,422	529	10,951
Large	20,849	1,552	22,399	18,363	1,629	19,992
Very Large	10,848	2,416	13,265	9,624	2,760	12,383
Mega	5,547	6,827	12,375	8,237	12,705	20,943
Total	59,054	12,132	71,186	55,278	18,430	73,708

Notes: a/ Traditional region includes seven states in the Midwest, namely IA, IL, IN, MO, MN, NE, and SD
b/ Emergent region includes six states in the Southeast, namely AL, AR, GA, NC, SC, and VA.
c/ Definition of the farm sizes, based on annual hog sales, is as follows: Small: <500, Medium: 500-999, Large: 1000-2999, Very Large: 3000-7499, Mega: >7500

Table 3: Location and Capacities of Major Processing Plants (1000 hogs per day).

	1992	1995	1998 [a/]
ALBER_MN	8	0	0
AUSTI_MN	11	13	16
BEARD_IL	14.2	16	16
CBLUF_IA	7.3	8	7.3
CINCI_OH	5	0	0
CLINT_NC	0	6	8
CRETE_NE	8.3	8.3	8.3
DELPH_IN	13	13	13
DENIS_IA	7.5	7.5	7.5
DETRO_MI	13.5	16.5	14
DMOIN_IA	5.5	0	6
DUBUQ_IA	11	0	11
FREMO_NE	6.2	6	11.7
GUYMO_OK	0	8	15
HATFI_PA	10	10	7
HURON_SD	5.8	0	7.6
LOGAN_IN	6.1	0	15
LOUIS_KY	10.4	10.4	3
MADIS_NE	7.5	7.2	7.5
MARCH_MO 8	0	11.8	
MARSH_IA	15.8	15.8	15.7
MILAN_MO	0	5	5
MONMO_IL	8.5	7	7
MOULT_GA	4.2	4	0
OTTUM_IA	10	9.8	10
PERRY_IA	6.3	5.5	6.7
ROCHE_IL	6.6	7	7
SIUXC_IA	13	13.5	13.5
SIUXF_IA	15	17	15
SMITH_VA	18.9	19.3	18.3
SPRFI_KY	3.7	0	0
STJOS_MO	9.6	0	0
STORM_IA	13	13	13.4
TARHI_NC	8	24	32
WATER_IA	15	19	17
WESTP_MS	6.5	0	6.5
WORTH_MN	15.8	15.8	15.7

Note: a/ 1998 capacities are predicted capacities

Table 4: Summary of the Results (all costs are in $million).

Run Id. [a]	Total Cost	Processing Cost	Production & Delivery Cost	Distribution of Deliveries by Mileage Category (%) 0-50	50-100	100-200	200-400	400+
S92/P92	7,947.8	1,584.8	6,363.0	30.4	33.1	20.8	11.5	4.2
S92/P95	7,949.6 (1.8) [b]	1,587.8 (3.0)	6,361.8 (-1.2)	29.4	34.8	22.6	9.5	3.7
S95/P92	8,540.3 (592.5)	1,696.9 (112.1)	6,843.4 (480.4)	16.7	23.3	29.0	15.3	15.7
S95/P95	8,445.6 (497.8)	1,696.4 (111.5)	6,749.2 (386.2)	23.6	27.7	29.9	13.3	5.5
S95/P95/C95	8,527.1 (579.3)	1,772.7 (187.9)	6,754.4 (391.4)	23.5	27.9	29.5	13.6	5.5
SPMAX	8,344.9 (-100.7) [c]	1,689.4 (-7.0)	6655.5 (-93.7)	37.6	40.5	15.9	4.5	1.5

Notes:

a/ The three numbers identifying each run refer to the year considered for hogs supply potential, processing capacity, and cost structure (including both production and processing costs), respectively. The last run assumes the maximum of 1992 and 1995 for both supply potential by region and processing capacity by plant location.
b/ The figures in parentheses are differences from the corresponding cost values in the S92/S92 run.
c/ The figures in parentheses are differences from the corresponding cost values in the S95/S95 run

Table 5: Peak Season Overtime Capacity Utilization in Selected Plants (1000 hogs).

	S92/P92	S92/P95	S95/P92	S95/P95	SPMAX
Traditional Region					
AUSTI_MN	13.5	111.3	94.1	111.3	0.0
BEARD_IL	77.5	155.3	137.9	155.3	0.0
CBLUF_IA	24.3	68.5	24.3	0.0	0.0
CRETE_NE	45.3	80.6	80.6	66.5	0.0
DELPH_IN	126.2	126.2	126.2	126.2	0.0
LOGAN_IN	59.2	n.a.	59.2	n.a.	0.0
LOUIS_KY	34.6	101.0	101.0	101.0	0.0
MARSH_IA	19.4	120.1	153.4	153.4	0.0
MARCH_MO	77.7	n.a.	77.7	n.a.	64.4
MADIS_NE	72.8	69.9	64.2	23.9	24.9
STORM_IA	71.0	126.2	43.2	43.2	16.4
WATER_IA	18.4	184.4	145.6	162.6	0.0
WORTH_MN	52.6	153.4	135.2	153.4	0.0
Subtotal	692.5	1296.9	1242.6	1096.8	105.7
Emergent Region					
CLINT_NC	0.0	51.3	n.a.	58.2	77.7
HATFI_PA	54.6	0.0	97.1	97.1	0.0
SMITH_VA	183.5	0.0	183.5	187.4	0.0
TARHI_NC	19.4	87.8	19.4	233.0	310.7
WILSO_NC	n.a.	6.7	n.a.	19.4	19.4
Subtotal	257.5	145.8	300.0	595.1	407.8

Table 6: Shadow Prices of Supply Constraints for Selected Representative Farms ($/hog).

	S92/P92		S92/P95		S95/P92		S95/P95		SPMAX	
	Large	Mega a/	Large	Mega	Large	Mega	Large	Mega	Large	Mega
Traditional Region										
IA_NE	51.83	59.70	46.66	54.54	50.75	58.62	46.95	54.82	18.95	26.82
IA_WE	51.33	59.20	46.83	54.70	52.62	60.49	47.91	55.78	18.80	26.68
IL_NW	50.49	58.56	45.56	53.64	47.66	55.54	45.33	53.41	18.13	26.21
IL_WE	50.40	58.48	45.48	53.55	47.27	55.35	45.05	53.13	18.21	26.28
IN	49.01	57.05	41.78	49.82	43.31	51.34	41.17	49.21	17.65	25.68
MN	52.28	59.96	47.70	55.08	52.36	60.04	47.40	55.08	19.40	27.08
MO	48.44	56.51	43.07	51.15	35.64	44.21	42.84	50.92	15.87	23.94
NE	49.69	57.65	45.19	53.15	50.97	58.94	46.66	54.63	17.22	25.19
OH	49.91	57.89	44.65	52.63	41.91	49.90	44.04	52.03	17.25	25.23
SD	54.24	61.75	49.55	57.06	54.51	62.02	49.55	57.06	20.88	28.40
Emergent Region										
NC	39.41	47.98	42.51	51.09	27.71	36.28	31.79	40.36	12.16	20.73

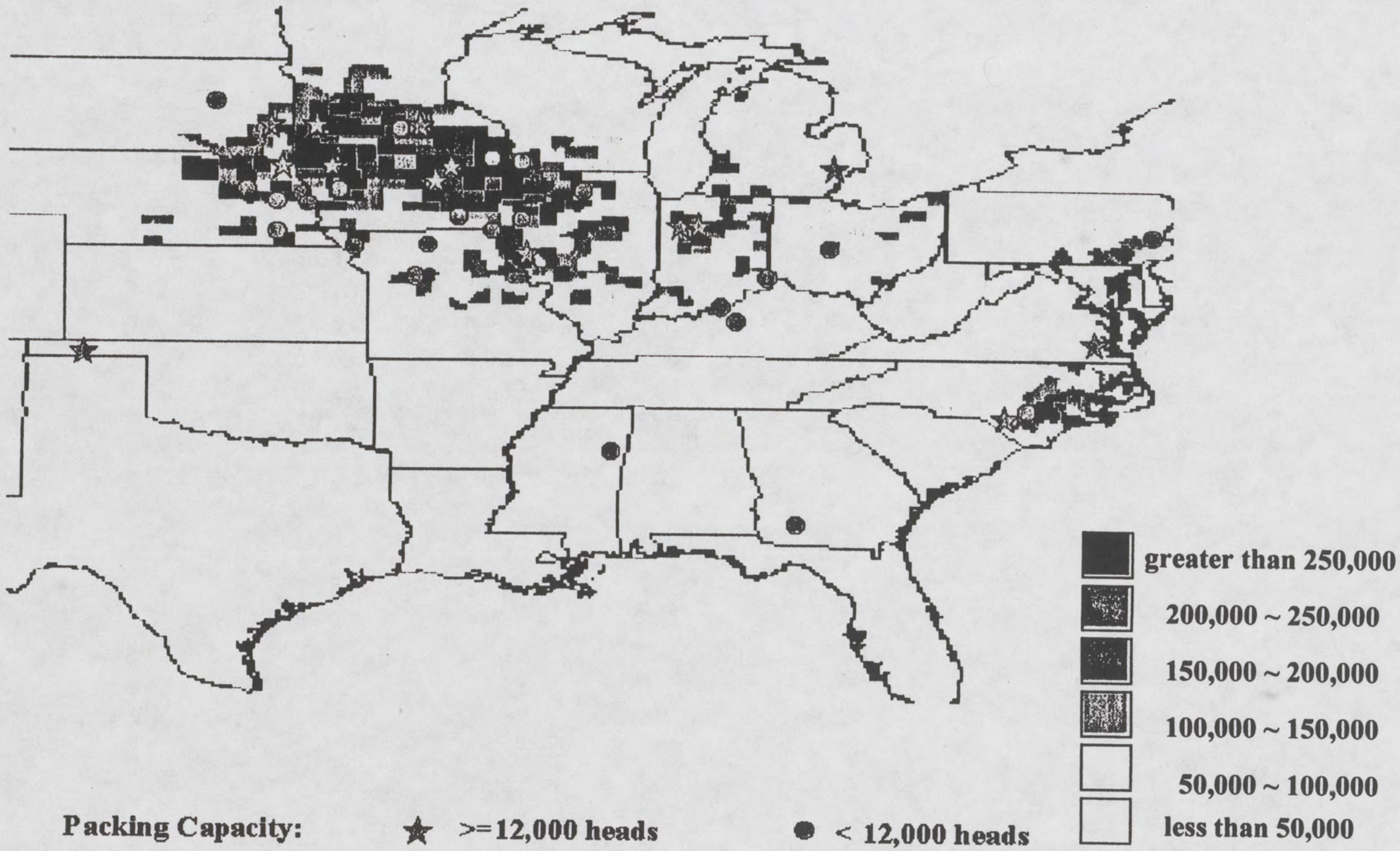
Note: a/ *Large* farms produce 1000-3000 hogs per year, *mega* farms produce more than 7500 hogs per year.

Table 7: Shadow Prices of Selected Processing Plants ($/hog).

	S92/P92	S92/P95	S95/P92	S95/P95	SPMAX [a/]
Traditional Region					
AUSTI_MN	20.50	24.23	24.23	24.23	20.50
BEARD_IL	24.23	24.23	24.23	24.23	20.50
CBLUF_IA	23.03	24.23	22.88	20.50	20.50
LOGAN_IN	24.23	n.a.	24.23	n.a.	20.50
MADIS-NE	24.23	24.23	24.23	22.70	22.70
MILAN_MO	n.a.	24.23	n.a.	24.23	20.82
SIUXC_IA	22.35	24.23	20.50	20.50	20.50
SIUXF_IA	20.50	20.75	20.50	21.81	20.50
Emergent Region					
GUYMO_OK	n.a.	20.50	n.a.	22.60	20.50
HATFI_PA	24.23	20.50	24.23	24.23	20.50
TARHI_NC	24.23	24.23	24.23	24.23	24.23
CLINT_NC	n.a.	24.23	n.a.	24.23	24.23
SMITH_VA	24.23	20.50	24.23	24.23	20.50
WILSO_NC	n.a.	22.99	n.a.	24.23	24.23

Note: a/ This run assumes the maximum of farm supply and processing capacities in 1992 and 1995
b/ These plants were assumed to be not in operation.

Figure 1: Sales of Market Hogs and Locations of Hog Packing Plants



Appendix A: Mathematical Specification of the Model

The mathematical model consists of two linear programs (LP) solved successively. The first LP minimizes total cost to the industry considering major hog producing states as aggregate supply units (except Iowa and Illinois which are divided into four and six subregions, respectively). This "first-stage model" is described below:

$$\text{Minimize Total Industry Cost (Z)} = \sum_{p,r,f} c_{prf} X_{prf} \qquad [1.1]$$

such that:

$$\sum_{r,f} X_{prf} \le a_p \quad \text{for all p} \qquad [1.2]$$

$$\sum_{p} X_{prf} \le s_{rf} \quad \text{for all r,f} \qquad [1.3]$$

$$\sum_{p,r,f} X_{prf} = v \qquad [1.4]$$

$$X_{prf} \ge 0 \quad \text{for all p,r,f} \qquad [1.5]$$

where p, r and f denote processing plants, supply regions, and farm types (by size), respectively; X_{prf} represents the number of hogs shipped from farm type f in region r to processing location p; a_p is processing capacity of plant p; s_{rf} is maximum available supply at supply location r ; and v is the total amount processed annually by all processing plants. Equation [1.2] states that the sum of shipments to a plant from all regions and farm categories (which equals the amount of processing) cannot exceed the processing capacity of that plant. Equation [1.3] restricts the sum of shipments from each farm category to the maximum capacity assumed for that farm. Equation [1.4] equates the total number of hogs processed by all firms to the amount v, which is exogenously specified and assumed to be equal to the total amount of processing in a given year (1992 or 1995).

The shadow prices λ_p and β_{rf} (both ≤ 0) associated with equations [1.2] and [1.3] measure the rate of change of total industry cost with respect to individual firms' processing capacity and farms' supply potential, respectively. Their non-positive signs indicate that the total industry cost would remain the same or decrease if an expansion occurs in either a processing firm's capacity or a farm's supply potential. Table 7 reports the absolute values of λ_p and β_{rf} which provide a ranking of processing firms and farm categories according to their economic importance to the industry (or comparative advantage).

Table 8: Implications of Salmonella Contamination Regulation on the Supply and Processing Structures.

	Maximum Contamination Ratio [a]				
	35%	30%	25%	20%	19%
Industry Cost ($million):					
Production & Delivery	6,685.4	6,735.2	6,801.6	6,873.1	6,907.2
Processing	1,690.2	1,689.3	1,690.2	1,688.6	1,689.8
Total	8,375.6	8,424.5	8,491.8	8,561.7	8,597.1
Distribution of Shipments (%):					
less than 100 miles	73.4	70.2	65.6	57.3	55.0
more than 100 miles	26.6	29.8	34.6	42.7	45.0
Total Production (1000 hogs):					
Traditional area [b]	52,801 (64) [e]	52,775 (64)	55,652 (68)	57,641 (71)	57,641 (71)
Emergent Area [c]	13,378 (16)	13,778 (17)	9,529 (12)	5,935.9 (7)	5,829 (7)
Processing (1000 hogs):					
Traditional area [b]					
Overtime	149	161	453	248	508.5
Total	56,103 (68)	53,892 (65)	55,652 (68)	62,233 (76)	63,560 (77)
Emergent Area [d]					
Overtime	595	287	10	10	10
Total	15,806 (19)	14,839 (18)	9,529 (12)	4,337 (5)	2,978 (4)

Notes: a/ Ratio of the number of contaminated animals over the herd size.
b/ Traditional area includes Iowa, Illinois, Indiana, Minnesota, Missouri, Nebraska and S. Dakota.
c/ Emergent area includes N. Carolina only
d/ Emergent area plants include N. Carolina and Virginia plants only
e/ Figures in parentheses represent percentages of production /processing in total production/processing.

The above approach underestimates the transportation costs due to aggregation of supply locations into aggregate regions. In order to reduce aggregation errors and obtain an optimum delivery pattern at county level, a second LP model is developed and solved for each region separately. The model finds the minimum cost delivery plan from all counties in a given region to the subset of processing plants that received positive shipments from that region in the aggregate model solution. Supply restrictions in this model incorporate the county-level maximum supplies while the sum of deliveries from all counties to a particular plant equals the amount found in the first stage LP model. An algebraic description of this model is given below for region r and $p \in \wp = \{p : X_{prf} > 0\}$:

$$\text{Minimize} \quad \sum_{p,k,f} c_{pkf} Y_{pkf} \qquad [2.1]$$

such that:

$$\sum_{f,k} Y_{pkf} \leq a_p \quad \text{for all p} \qquad [2.2]$$

$$\sum_{p} Y_{pkf} \leq s_{kf} \quad \text{for all f, k} \qquad [2.3]$$

$$\sum_{k} Y_{pkf} = X_{prf} \quad \text{for all p, f} \qquad [2.4]$$

$$Y_{pkf} \geq 0 \quad \text{for all p, k, f} \qquad [2.5]$$

where k is the index for counties in region r; Y_{pkf} represents the number of hogs shipped from farm type f in county k to processing location p; and all other symbols are as defined before. The total costs reported in Table 4 are obtained by summing the optimum costs across regions found in the second stage LP model defined by equations [2.1]-[2.4].

Appendix B: Data Sources

Farm supply: Several sets of 1992 Census data (published and special unpublished tabulations) were used in order to provide supply data for thirty selected states[1]. Published 1992 Census data include total state and county sales of hog (feeder pigs not included), as well as sales distribution by farm size at the state level[2]. In order to obtain size categories comparable with available cost data, farms were categorized into five size categories based on annual sales: small (below 500 hogs), medium (sales between 500 and 999 hogs), large (sales between 1000 and 2999 hogs), x-large (sales between 3000 and 7500) and mega farms (sales above 7500 per year).

At the county level, published Census data provide only total sales by counties but without sales distribution by farm sizes[3]. In order to obtain county sales distribution by farm size categories, data for counties with annual sales above 50,000 were specially requested from CENSUS[4]. We estimated values for sales categories that could not be disclosed due to confidentiality.[5] Farm

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[1] Alabama, Arizona, Arkansas, Colorado, Georgia, Florida, Iowa, Illinois, Indiana, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Mississippi, Montana, North Carolina, North Dakota, New York, Nebraska, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, South Dakota, South Carolina, Virginia, Wisconsin

[2] According to number of hog sold per year, Census defined ten different farm size categories (1-24, 25-49, 50-99, 100-199, 200-499, 500-999, 1000-1999, 2000-4999, 5000-7500 and above 7500 hogs per year).

[3] In addition, sales from counties with a small number of farms were disclosed. Such counties are categorized into one category – "others", and their sales were computed as the difference between total state sales and sum of "known" county sales.

[4] Only 13 out of 30 states had counties with sales above 50,000 hogs per year: Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, North Carolina, Nebraska, Ohio, Pennsylvania, South Dakota, Wisconsin

[5] The special runs reported a "D" for non-disclosure in some counties for some size categories. If non-disclosed data is in one size category, Census policy requires random non-disclosure in an additional category for the same county. In order to provide consistent estimates of category sales at county level, we requested that the additional disclosure be assigned to the next size category.
The residual between total county sales and known sales for each county (UN) was separated into two non-disclosed categories by two different ways. If disclosure data were in large and mega farm categories, sales from mega farm was computed first using formula (1).

$$(UN+CN_{1000\text{-}3000})*(S_{7500}/S_{1000\text{-}7500})*[(UN+CN_{1000\text{-}3000})/CT]/[(S_{7500}/S_{1000\text{-}7500})/ST] \quad (1)$$

where:
$(UN+CN_{1000\text{-}3000})$ is county sales above1000
$S_{7500}/S_{1000\text{-}7500}$ is % of state sales above 7500 into state sales above1000
$(UN+CN_{1000\text{-}3000})/CT]/[(S_{7500}/S_{1000\text{-}7500})/ST$ = ratio of percentage of sales above 1000 hogs in total county sales and percentage of sales above 1000 hogs in total state sales.
In a few cases where computed sales for mega farms were below 7500, we assigned a minimum sales value of 7500 to the mega farms in those counties. County sales from large farms was computed as a difference between the residual and sales from mega farms.

structure in 1995 was estimated using 1992 Census data as a basis, and estimates of growth in sales from USDA/NASS hog inventory and sales data.[6] This is necessary because the reported Census sales do not exactly match the 1992 reported USDA sales.

Farm cost data for 1992 is constructed from two sources (Purdue Cooperative Extension Service and the USDA/ERS Farm Costs and Returns Survey). Purdue Cooperative Extension estimated costs for large, x-large and mega farms, and McBride reports FCRS cost data for small and medium farms[7]. Cost data include feeds, other purchased inputs, labor, and capital depreciation. Different hog weights by farm size are based on the Purdue study (large, x-large and mega farms) and FCRES data (small and medium farm sizes).

Processing Plant data: Location and maximum daily capacity of large slaughtering plants are based on Iowa State University data.[8] Total annual capacities were computed based on 250 working days. State processing capacities were adjusted by percentage of sales to the small plants

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In several cases where sales from mega farms were zero, and sales from x-large and large farm size categories were not disclosed, the residual was equally divided between the two size groups.
For a few countries that have non-disclosed data in three farm size categories, we first assumed sales in the smallest size category up to the upper limits (5 farms times maximum sales in category). The remaining sales residual was then equally distributed between the two larger size categories.
Sales by farm size from counties with annual sales less then 50,000 ("marginal") and counties with undisclosed total sales were obtained as differences between state sales and sum of county sales for each size category. Residuals for each size category were distributed first to the "marginal" counties according to county total sales, and remainder of sales were assigned to counties with disclosed total sales.

[6] Total sales in 1992 were multiplied with 95/92 ratio of NASS hog marketing data to obtain an estimate for total sales in 1995. Sales from mega farms in 1992 were multiplied by NASS inventory ratio 95/92 for mega farms in order to capture faster growth of sales from mega size farms. After subtracting mega farms sales from total sales, the remaining sales were divided among small, medium, large and x-large farms in same proportion as in 1992. This may underestimate reductions in sales from the smallest sales categories, but captures the most important distribution shift towards the very largest farms.

[7] In order to provide comparability among cost structures, Purdue meal prices and input-output coefficients were used for all farm sizes. FCRS tax and insurance costs were excluded and corn price is assumed same for both small and medium size farms. Land cost was assumed same for all farm sizes.

[8] Personal interview with Dr. Hayenga provided data for 1992-1995. Capacity estimation for 1998 was obtained from NPPC web page.

(Packers and Stackers Report and special regional tabulations). Processing costs data[9] (Hayenga, 1997) were deflated by the chain-type price index for non-durable good for 1992 and 1995 (Economic Report of the President, 1997).[10]

Transportation distances: Distances between plants and county centers were computed using U.S. Census Geographic Information Coding Scheme (GISC). Distances between demand and supply points were calculated as a summation of longitudinal and latitudinal differences multiplied by average distance (in miles) between two consecutive degrees.

Transportation costs: Average yearly transportation costs for 1995 (USDA/ERS) were assumed same for 1992 and 1995, since an index of agricultural trucking costs (U.S. Department of Labor, Bureau of Labor Statistics, Producer Price Index) did not show significant changes between 1992 and 1995.[11]

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[9] Hayenga (1997) estimated 1996 processing cost for two sizes of hog slaughtering plants (above and below 10000 hogs/day) with one or two shifts, and two intensities (regular time and overtime).

[10] This index was also used by Huffman and Melton in their study of meat processing costs over time.

[11] In addition, several hauling companies from the Midwest were interviewed during 1997 and 1998 in order to provide comparison with USDA data.

Appendix C: Estimates of Salmonella Prevalence by Farm Size and Region

The USDA/APHIS conducted a National Animal Health Monitoring Survey of pork producers in 1995. The survey included a statistically valid sample of producers who answered questions regarding farm practices related to animal health. In addition, about 160 producers out of the original sample elected to participate in collection of 50 fecal samples from their farms. A total of 6,655 samples were collected from 988 pens on 152 operations. These were tested by the National Animal Disease Center for the presence of salmonella and other food borne pathogens. USDA/APHIS reported a general overview of the salmonella results in their information sheet series (available on the web at www.aphis.usda.gov/vs/ceah/cahm). APHIS (1997) reports that evidence of salmonella was found on 38.2 percent of operations; that a greater proportion of operations were positive in the southeast (65.5%); and that salmonella incidence increased with herd size to 57.1% for farms marketing 10,000 or more head annually.

We obtained the original survey data and used it to estimate the probability of salmonella contamination by farm size and region of the country, with categories constructed so as to match as closely as possible the regional supply and demand model. The percent of pigs positive for salmonella on each farm is the dependent variable in a probit function with independent variables for number of animals marketed per year, region, and production system (Appendix Table C1). The parameter estimates show that mega farms (sales 7500 or more annually) and the southeast region (GA, KY, NC, TN) have significantly higher incidences of salmonella, as expected. Although farms in the southeast tend also to be mega-farms, the data contain sufficient observations in each region/size category to distinguish between the effects of farm size and location on salmonella incidence. We use the parameter estimates to generate the expected percent positive by farm size and region (Appendix Table C2). These are used in the regional supply and demand model results reported in the body of the paper.

Appendix Table C1: Probit Estimates of Salmonella Incidence

Variable	Parameter estimates	[Pr > Chi Square]
Intercept	-2.5214	0.0001
MED	0.7336	0.1622
LRG	0.6157	0.2487
VLRG	1.0339	0.0536
SE	0.5998	0.0089
ECB	0.4145	0.1084
PLA	-0.0617	0.8009
FTF	0.0739	0.7897

The intercept represents Midwest small farms who are grower/finishers. Small farms are those that market less than 1,000 animals per year. The Midwest includes the states of Illinois, Iowa, Michigan, Minnesota, and Wisconsin. Farm size dummy variables are equal to one for these categories: MED-- sales of more than 999 and less than 3,000; LRG– sales of more than 2,999 and less than 7,500; VLRG– sales of more than 7,499. Region dummies are equal to one for the following groups of states: SE– GA, KY, NC, TN; ECS– OH, PA, IN; PLA– KS, MI, NE, SD. The FTF dummy is equal to one when the farm is a farrow to finish operation.

Appendix Table C2: Salmonella Probabilities Estimated from the Probit Model (Farrow to Finish farms)

Category	Probit(p)	Prob. P(positive)	Exp [Probit (p)]
Small farms, Midwest	-2.4475	0.007	0.09
Small farms, South East	-1.8477	0.033	0.16
Small farms, Eastern Corn Belt	-2.033	0.021	0.13
Small farms, Plains	-2.5092	0.006	0.08
Madium farms, Midwest	-1.7139	0.044	0.18
Medium Farms, South East	-1.1141	0.134	0.33
Medium farms, East Corn Belt	-1.2994	0.099	0.27
Medium Farms, Plains	-1.7756	0.038	0.17
Large farms, Midwest	-1.8318	0.034	0.16
Large Farms, South East	-1.232	0.111	0.29
Large farms, East Corn Belt	-1.4173	0.079	0.24
Large Farms, Plains	-1.8935	0.029	0.15
Very large farms, Midwest	-1.4136	0.079	0.24
Very large farms, South East	-0.8138	0.209	0.44
Very large farms, East Corn Belt	-0.9991	0.161	0.37
Very large farms, Plains	-1.4753	0.071	0.23